Responses of soil quality indicators to three crop rotation systems in paddy soils

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1. Abstract

This study conducted to detect effects of rice crop rotation with two species of legume on soil quality indicators in compared to rice-fallow rotation system in Amol area, Northern Iran. Three studied plots were located adjacently and managed over 10 years (since 1995 till 2005) similarly by a farmer. Surface soil samples from 0-30 cm depth were collected from forty randomly selected points in each three rotation systems using a hand auger in October 2005 after harvesting. A total of 120 samples were air-dried and passed through 2 mm sieve to remove stones, roots and large organic residues for chemical, biological and some physical measurements. The laboratory measurements included pH, EC, $CaCO_3$, total N, available P, available K, CEC, OM, MWD, microbial respiration, microbial Carbon biomass, and bulk density. Statistical analysis was done using SPSS. Statistical results revealed that frequency distribution of most data was normal. The lowest CV% was related to pH. Analysis of Variance (ANOVA) and comparison test showed that there were the significant differences in soil quality indicators between understudy crop rotation systems. Results of multivariable regression analysis revealed that soil respiration and microbial biomass carbon had high correlation coefficients with soil organic matter and MWD. Overall results indicated that the rice rotation with legumes such as bean and clover over a long time improved soil quality in compared to rice-fallow rotation.

2. Introduction

Land use planning according to soil suitability is a well-known technology for long term sustainable land, management. However change in time and space and the suitability use may also have to be reviewed (Paz Gonzalez *et al*., 2000). Changes in soil properties due to use and management and their consequences to the environment and to the production capacity have been studied (Evrendilek *et al*, 2004; Paz Gonzalez, 2000). Rice and wheat crops occupy vast areas in the agricultural ecosystem and provide a large portion of the world's population, especially in Asia with staple food (Ma *et al*, 2007). Rice is the second main food consumed in Iran, and its consumption dates back more than 25 centuries Iran's average area under rice cultivation is over 500,000 hectare and average output is 4 tons/hectare.

Intensive rice cultivation in paddy soils may be leaded to diminish soil quality and productivity over a long time. Loss of organic matter due to rice cultivation without restoration may initiate physical degradation processes. Very often, the process of depleting the soil of its natural resources when submitted to any given agricultural production system is put and what is taken out of the soil. To evaluate the effects of repeated traditional cultivation, fence line comparisons between different adjacent land use systems, have been done for a number of chemical, physical and morphological soil properties (Paz Gonzalez *et al*., 2000).

The wet Caspian lowlands in the northern provinces of Gilan and Mazandaran are the primary growing areas, where heavy rainfall typically facilitates paddy cultivation in this sub-tropical, humid region. In paddy soils of Mazandaran province The most important crops including rice(*Oryza sativa*), bean(*Vicia faba*) and clover(*Trifolium repens*) defined three crop rotation systems as following: 1) Rice-Follow(R-F) 2) Rice-Clover(R-C) and 3)Rice-Bean(R-B). In two later crop rotation systems clover and bean cultivated after rice harvesting. Although for a long time, the described crop rotation systems have been performed in the study region, but few studies have taken into account the rotation system of rice and legumes on soil quality indicators. Soil quality as a concern for sustainable global development was defined to conserve soil productivity and water, air and human health under sustainable land uses. Soil quality investigations are needed to provide information for management and regulatory decisions. Soil quality indicators usually are used to assess soil quality in an ecosystem. The objective of this study was to detect effects of different crop rotations (as above described) in paddy soils on some soil physical, chemical and biological attributes.

3. Materials and Methods

The study area is located in 36° 25 32 northern latitudes, and 52° 25 40 eastern longitudes in Dashtsar village, located 8 km of Amol, Mazandaran province, northern Iran.(Fig 1) The mean annual temperature at the site is 16 C. The mean annual precipitation is 848 mm, which 75% of that, falls from November up to March. According to USDA classification (Soil Survey Staff, 2006) the soil moisture temperature regimes are wet Ustic and Thermic respectively. Soils of the study area have been developed on river plain sediments which has less than 1% general slope. The studied field was managed by a farmer and uniform management. Within the filed were identified three individual rotation systems were operated for 10 years continuously since 1995 till 2005. The most important crops including rice, bean and clover defined three crop rotation systems as following: (1) Rice-Fallow[R-F] (2) Rice-Clover[R-C] and (3) Rice-Bean[R-B].

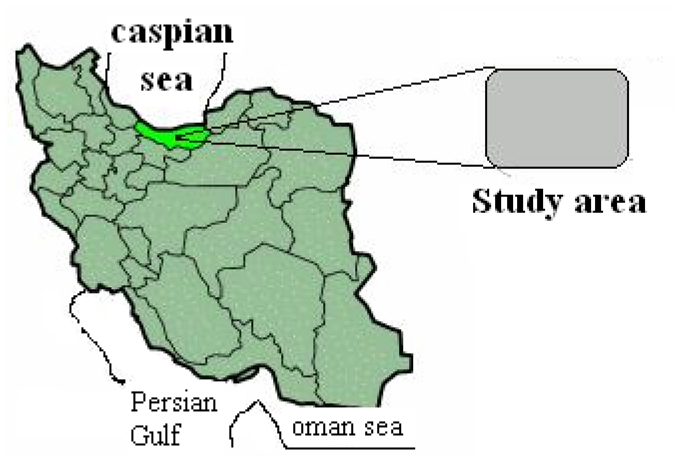

Figure 1 Location of the study area in Mazandaran province, northern Iran

Three adjacent plots (100×15 m) were selected to evaluate influences of crop rotation systems described before, on soil attributes in paddy soils. Soil sampling was performed in 44 points in each plot randomly, in early October 2005 after rice harvesting. Soil samples were collected from 0-30 cm depth using a hand auger, three sub-samples at 1 m^2 area in each sites, and then composed to reduce micro-variability. A total of 132 soil samples were air-dried and passed through 2 mm sieve to remove stones, roots and large organic residues for chemical and some physical measurements.

For detecting influences of selected rotation system on biological characteristics of soils, ten undisturbed soil samples in each plot were collected and microbial biomass C (MBC) and microbial respiration rate (MR) were measured as microbial indicators. Totally 30 soil samples analyzed for MBC by the fumigation-incubation methods (Jenkinson and Powlson, 1976), from the relationship $MBC=F_c/K_c$ where F_c=[(CO_2-C evolved from fumigated soil, 0-10 days)- (CO_2-C evolved from non-fumigated soil)] and K_c the proportion of microbial C evolved as CO_2= 0.45 for 10 days incubation at 25 C. Microbial respiration rate (MR) was measured by the closed bottle method of Anderson (1982). Particle size distribution and soil texture, soil bulk density was measured by core method. The soil samples were oven-dried at 105° C for 24 h and weighted to calculate bulk density, pH, EC, Calcium carbonate equivalent (CCE), soil organic carbon matter (SOM), total nitrogen (TN), available potassium (K_{ava}), cation exchange capacity (CEC), available phosphorous (P_{ava}), and mean weight diameter(MWD) were measured by standard methods(Page, 1982).Descriptive statistics in the form of mean, minimum, maximum, median, standard deviation, coefficient of variation, distribution of normality, range, skewness and kurtosis were determined. One-way analysis of variance (ANOVA) and mean comparison using Duncan's test and Pearson linear correlations among parameters were conducted using SPSS software.

4. Results and Discussion

The summary of the statistics for soil parameters in the given treatments showed that the parameters values are varied both and within plots. Variability in space and time for point data can give valuable insight into the dynamic nature of soil properties within a field's boundary. Management of this variability is worthwhile if the amount is high enough to justify the costs of obtaining the information or if this management will increase profit. The knowledge of the variability in soil properties is a key for designing site-specific management practices (Shukla *et al*., 2004). Lowest coefficient of variation (CV =0.01) was found for pH in three cropping systems. Several researches confirmed the lowest variability for pH that occurred within landscapes units of a few hectares or less (Shukla *et al*, 2004; Cox *et al*, 2003). The highest variability was found for MBC, CV= 0.89, CV= 0.76, and CV=0.46 in R-F, R-C and R-B respectively. It is suggested that a relatively high CV values for MBC may resulted from its relatively fast responses to management, and consequently responses more rapidly compared to other variables (Powlson *et al*., 1987). Moreover, Clay, Slit, bulk density, and K_{ava} were identified low variability (CV between 0.01 and 0.08) in all given treatments. On the other hand SOM, CCE, and P_{ava} were moderate variables in all treatments. The remaining parameters, showed different variability between treatments. In general R-B rotation treatment indicated lower variability for all soil parameters compared than the others. In overall, CV values for selected soil properties in this study were lower than those reported in other references; indicating probably to the homogenizing effect of the long-term cultivation and homogenous management on top soil. This finding is also in accordance with Paz Gonzalez *et al*., (2000).

The results of analysis of variance (ANOA) revealed that there are significant ($P>0.001$) differences between the studied treatments according to soil properties. To seek which soil attributes may be differed between studied treatments, mean comparison test (Duncan's test) was done, where the results have been shown in Table 1 and 2. The comparison of means indicated that no significant differences ($P<0.05$) in particle size distribution and this result emphasized on the appropriate selection of plots based on similar initial status. Also no significant differences for pH, EC mean values in three treatments, suggested that the different crop rotation had no influences on soil acidity and electrical conductivity. There are significant differences ($P<0.05$) for other selected soil attributes. Soil organic matter had the highest value in R-B rotation, but the lowest in R-F treatment (Table 2). It seems that cultivation of *Vicia faba* for a long time in rotation with rice led to an increase (32.35%) in the concentration of soil organic matter, compared to rice-fallow cultivation.

Table 1 Multiple Comparisons of mean values of soil physical attributes among three rotation systems (Duncan's method)

Crop rotation	Soil attribute				
	BD	MWD	Silt	Clay	Sand
R-F	1.69a	0.72c	468.4ns	386.4ns	145.2ns
R-C	1.65b	1.09b	483.2ns	360.5ns	156.3ns
R-B	1.57c	1.45a	476.6ns	365.8ns	157.6ns

a, b, c, … indicate significant differences ($p<0.01$) among treatments based on Duncan's mean test
ns :not significant at $P> 0.05$ level

Table 2 Multiple Comparisons of mean values of soil chemical and biological attributes among three rotation systems (Duncan's method)

Crop Rotation	Soil attribute									
	pH	EC	SOM	CCE	CEC	Pava	K ava	TN	MBC	MR
R-F	7.59ns	0.88ns	1.38c	9.28a	15.72b	30.26a	566a	3.3b	5.50b	0.09b
R-C	7.47ns	0.87ns	1.75b	8.62ab	20.45a	24.00b	577a	3.3b	6.05b	0.11b
R-B	7.44ns	0.81ns	2.04a	7.44b	22.24a	49.71a	480b	3.8a	17.76a	0.17a

a, b, c, … indicate significant differences ($p<0.01$) among treatments based on Duncan's mean test
ns :not significant at $P> 0.05$ level.

Soil organic matter has already reported as the most powerful soil attributes for assessing soil quality in different region of world under varied land uses and managements (Shukla *et al*, 2006, Ajami *et al*, 2006). The higher of soil organic matter combined with stronger aggregation probably accounted for the lower bulk density under R-C and R-B rotations compared to the R-F rotation(approximately 2.36 % and 7.1% respectively increases). This dependency of soil physical, chemical and biological attributes to SOM is consistent with findings of other researchers (Vagen *et a*l., 2006; Wang and Gong, 1998). Increased SOM improves aggregation, nutrient-retention capacity, colloidal characteristics, and biodiversity in soil. Because of the above effects of SOM, R-B and R-C rotation systems had more CEC, TN, MR, and MBC, compared to R-F rotation system (Table 1 and 2).

Soil microbial biomass (MBC) and microbial respiration rate (MR) were closely related to organic matter content and MWD in the studied soils. Because the C and N in the MB (MBC and MBN respectively) turn over rapidly and reflect changes in management practices long before changes in total soil C and N are detectable (Powlson *et al*., 1987; Fauci and Dick, 1994). Anomaly variations in K_{ava} and P_{ava} among the treatments and low their correlations with SOM indicated that the inorganic colloids of soils controlled the above nutrients and uncontrolled management practices like as irrigation and drainage affected their variability. The mean weight diameter of soil aggregates was significantly ($p<0.01$) different among crop rotation systems. Comparison test using Duncan's method showed that there was significant differences ($p<0.01$) among R-B (1.45 mm), R-C (1.09 mm) and R-F soils (0.72mm) (Table 1). Aggregate stability depends on interaction between primary particles and organic constituents to form stable aggregates, which are influenced by various factors related to soil environmental conditions and management practices. Increasing of soil organic carbon due to Legume cultivation is connected to construction of macro-aggregates.

5. Conclusion

To detect effects of crop rotation of rice cultivation with legumes in the study area in northern Iran, overall results showed that soil quality indicators have been affected by long-term management of rice cultivation in rotation with legumes compared to fallow-rice rotation. The most affected soil indicators included mean weight diameter, bulk density, microbial respiration and microbial biomass carbon. The overall results revealed that rice cultivation in rotation with legumes improved soil quality significantly compared to fallow-rice cultivation. Therefore it seems that to achieve the sustainability in the given ecosystem, rice-legume rotation could be more effectiveness.

6. References

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